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Title: Modeling Imperfect Composite Interfaces Using Abaqus

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Intended for: Present to my research group at my university to show them what I did this summer at my LANL internship

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Modeling Imperfect Composite Interfaces

Using Abaqus

Pablo Leon
Nathan Miller
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7/25/18

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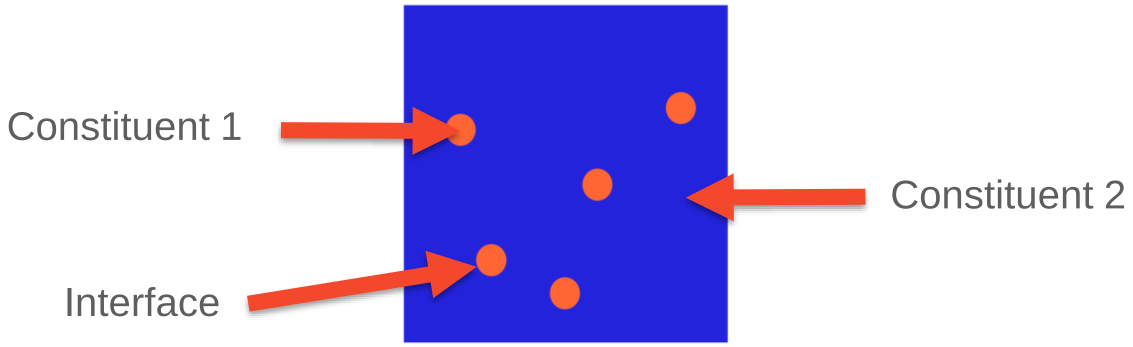
Overview

- **Project Objective**
- **Building Blocks**
  - Homogenization
  - Viscoelasticity
  - Partial Tie
- **Models Developed for Bonding Study**
  - Reaction Force Evolution
  - Damage as a function of crack growth
- **Results**
- **Questions / Future Work**
- **Acknowledgements**

Project Objective

Project Objective

- Investigate the effects of imperfect interface bonding on composite-level mechanical properties



“isostrain and isostress,” MIT OpenCourseWare, MIT. 2009.

Building Blocks

Homogenization

Building Blocks

- Voigt (isostrain/spring in parallel) or Reuss (isostress/springs in series)

- Measure homogenized modulus

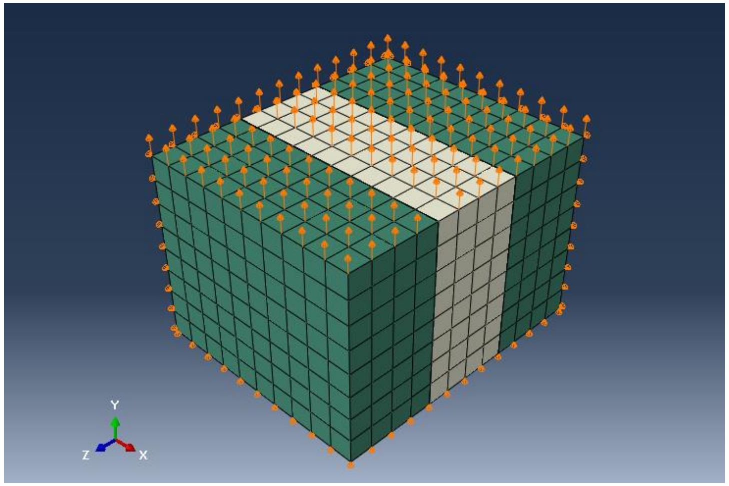
- $\bar{\sigma} = \frac{\sum RF_{top\ face}}{A_{i,top\ face}}$

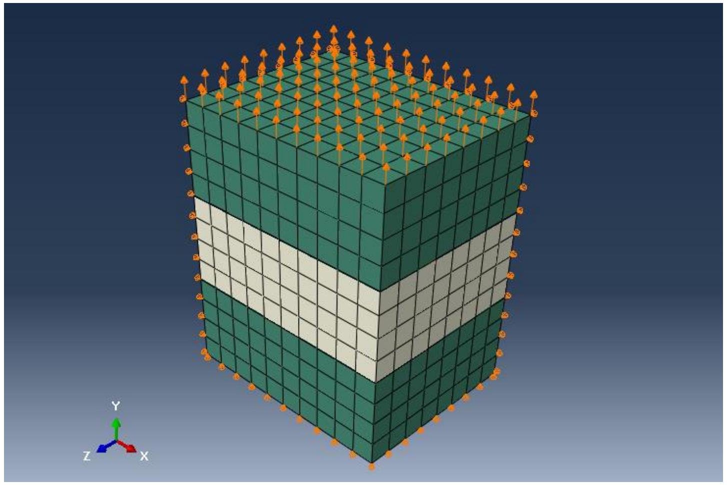
- $\bar{\sigma} = \frac{\sum(\sigma_{IVOL} * IVOL)}{\sum IVOL}$

- $\bar{\epsilon} = ln(\frac{y_i}{y_0})$

Idealized Voigt Modulus	Both Poisson's = 0	Same Poisson's Ratio (0.33 for Al)	Normal Material Properties
114,266	114,256	114,256	114,288

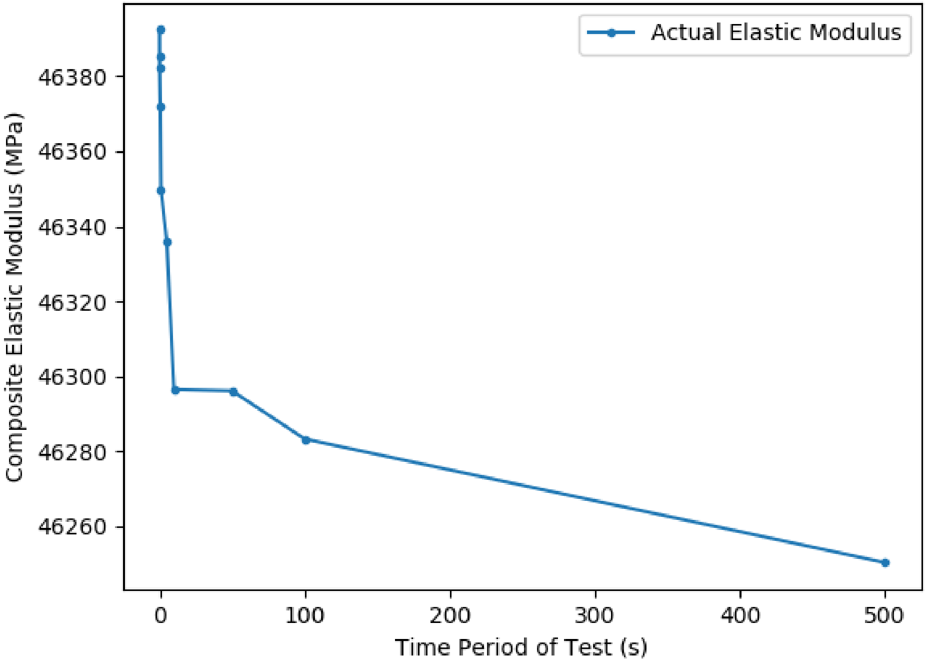
Idealized Reuss Modulus	Both Poisson's = 0	Same Poisson's Ratio (0.33 for Al)	Normal Material Properties
88,480	88,417	90,490	90,700





Viscoelasticity

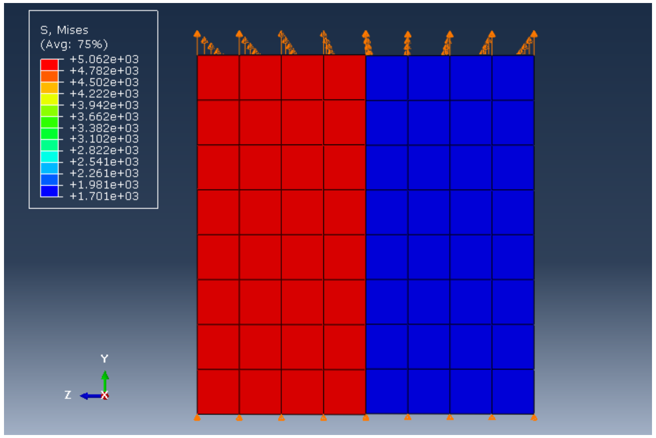
- Polyethylene was modeled to introduce viscoelasticity
- Much less stiff relative to aluminum and steel

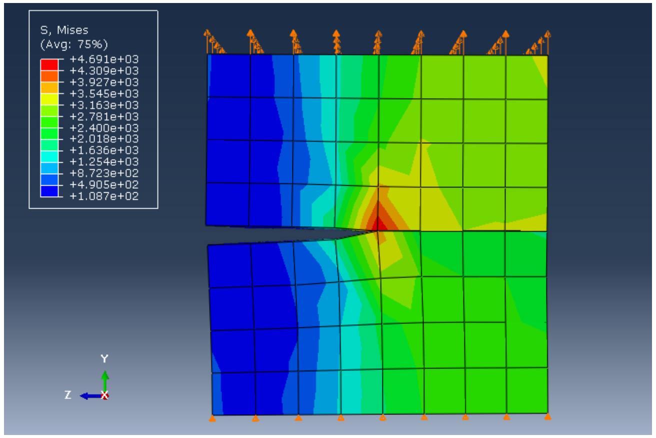


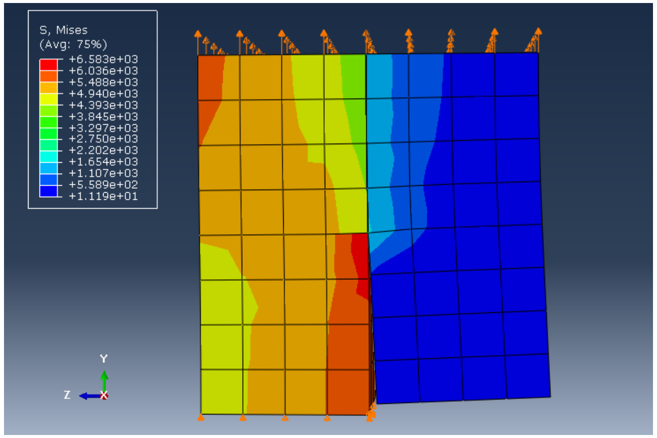
G_i (MPa)	g_R	t (s)
140.66	0.212	1.0E-01
97.46	0.147	1.0E+00
101.00	0.152	1.0E+01
62.31	0.094	1.0E+02
60.58	0.091	1.0E+03
21.13	0.032	1.0E+04
17.43	0.026	1.0E+05
8.91	0.013	1.0E+06
10.32	0.016	1.0E+07
19.30	0.029	1.0E+08

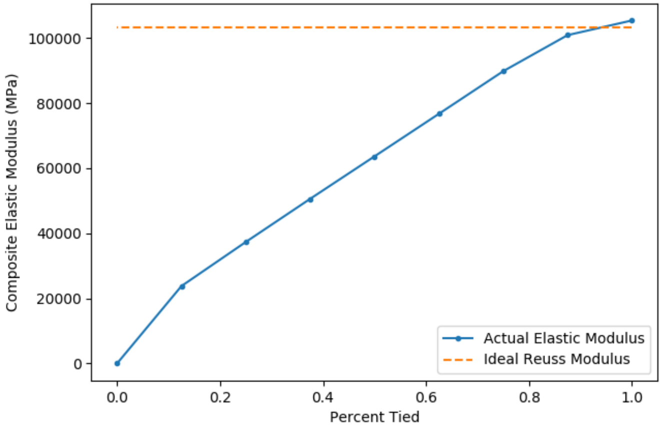
Partial Tie

- Tie does not matter in isostrain condition if top and bottom face are constrained
- Different amounts of deformations on element faces cause curving
- Notice how all results are seen face-on





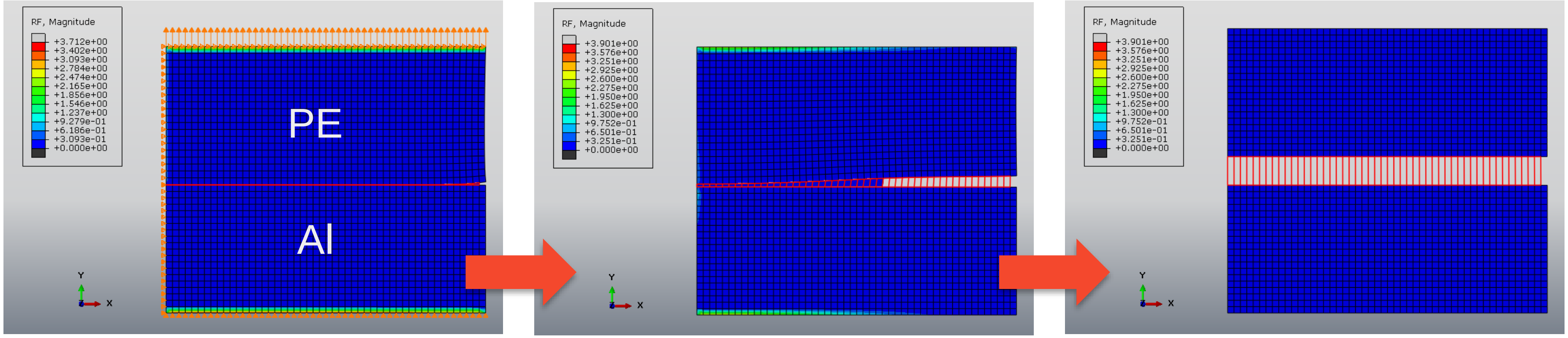




Models Developed

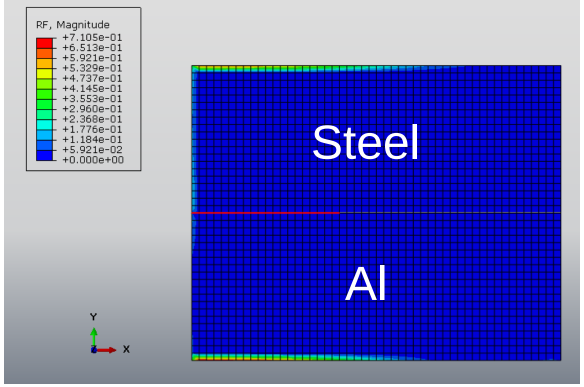
Models Developed for Bonding Study

- The reaction force vs displacement behavior of the composite was determined by initializing a small crack and uniformly displacing the top face until the crack was fully propagated and the two constituents separated



- The composite stiffness was found as a function of crack length by initializing specific crack lengths and uniformly displacing the top face such that the crack did not grow

- Al/Al
- Al/Steel
- Al/PE
- PE/PE

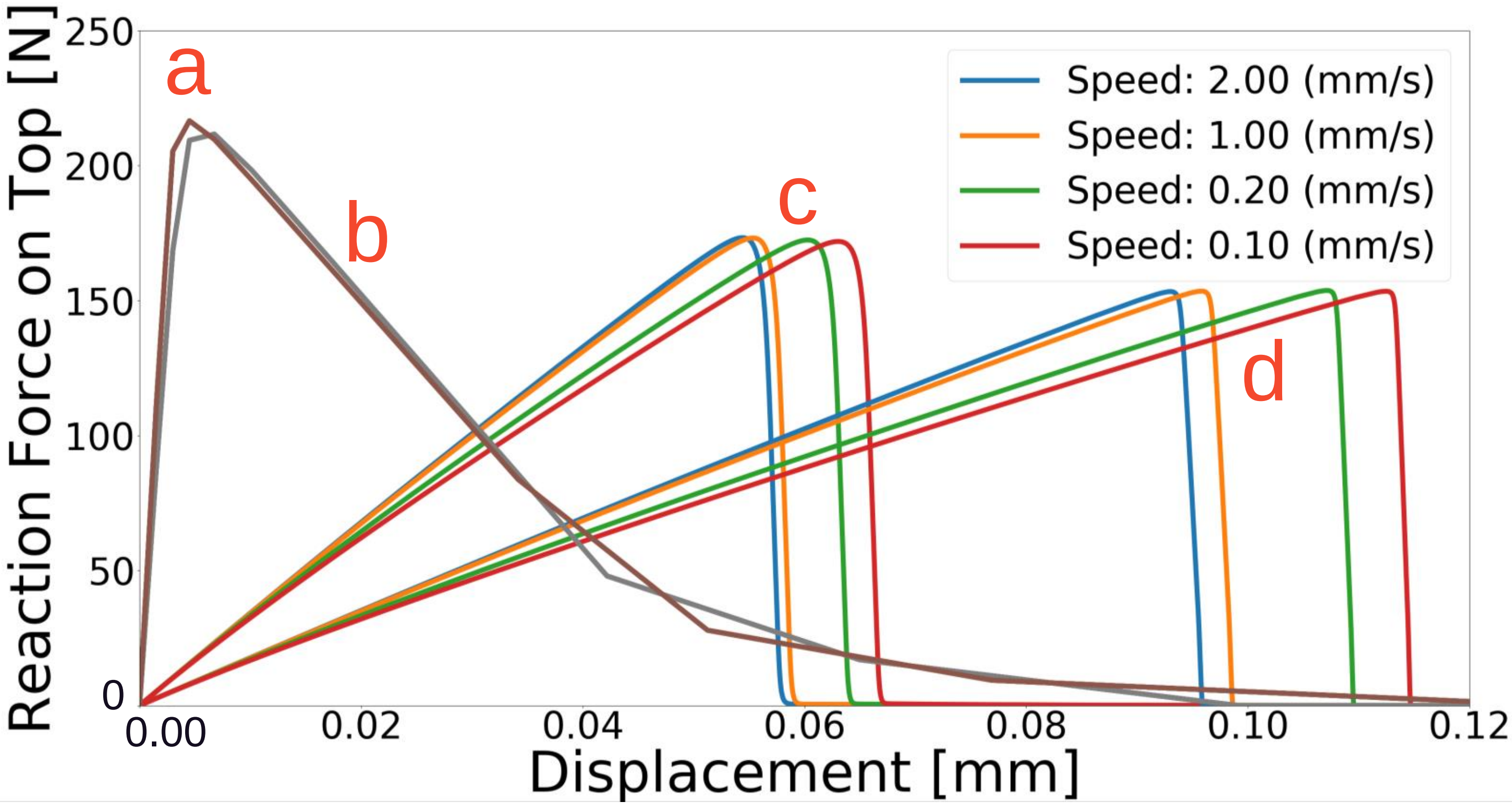


Results

Reaction Force Evolution

Results

- PE/PE had the highest strain rate dependence followed by Al/PE.
- Maybe more energy absorbed by Al/Steel and Al/Al?

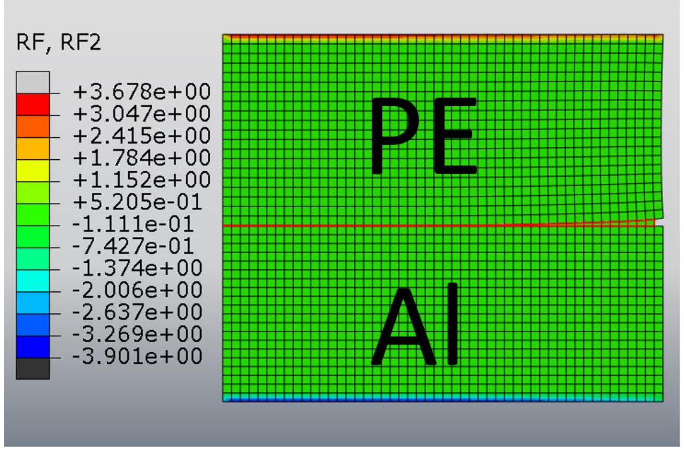


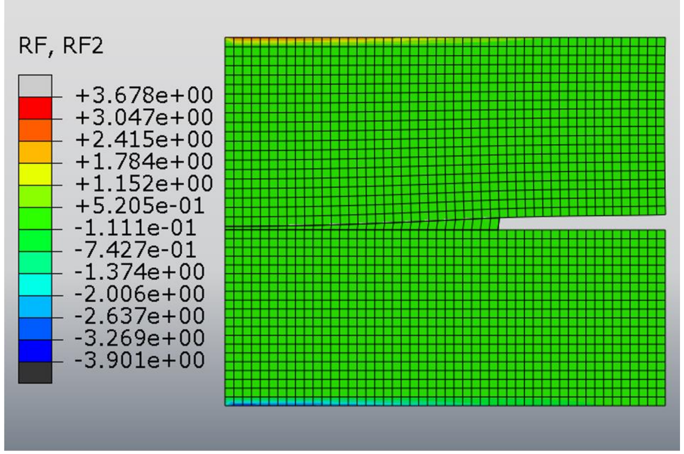
a) Al/Steel (brown) b) Al/Al (grey) c) Al/PE d) PE/PE

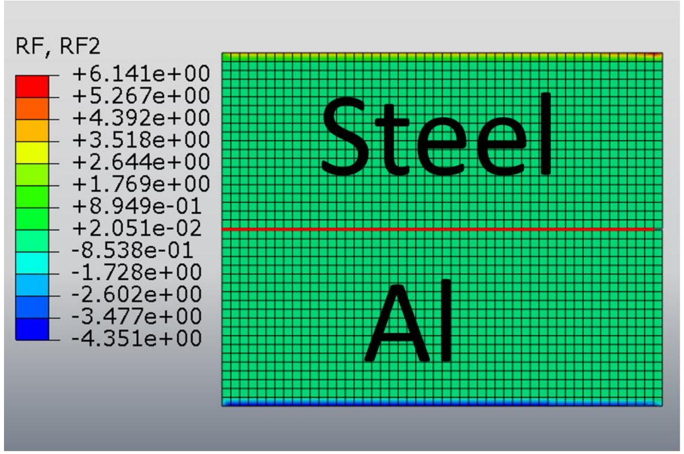
Reaction Force Evolution

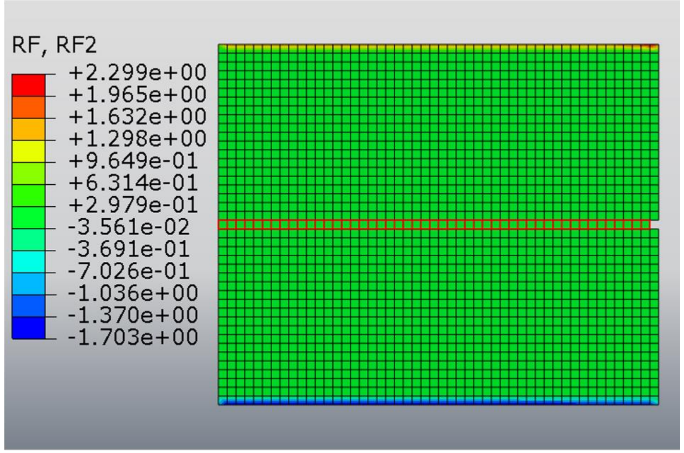
Results

- The crack in the Al/PE grew across the interface while the reaction forces only acted above the bonded area with a constant magnitude.
- The stiffer steel caused uniform breaking of bonds with decreasing reaction forces as the bonds weakened.





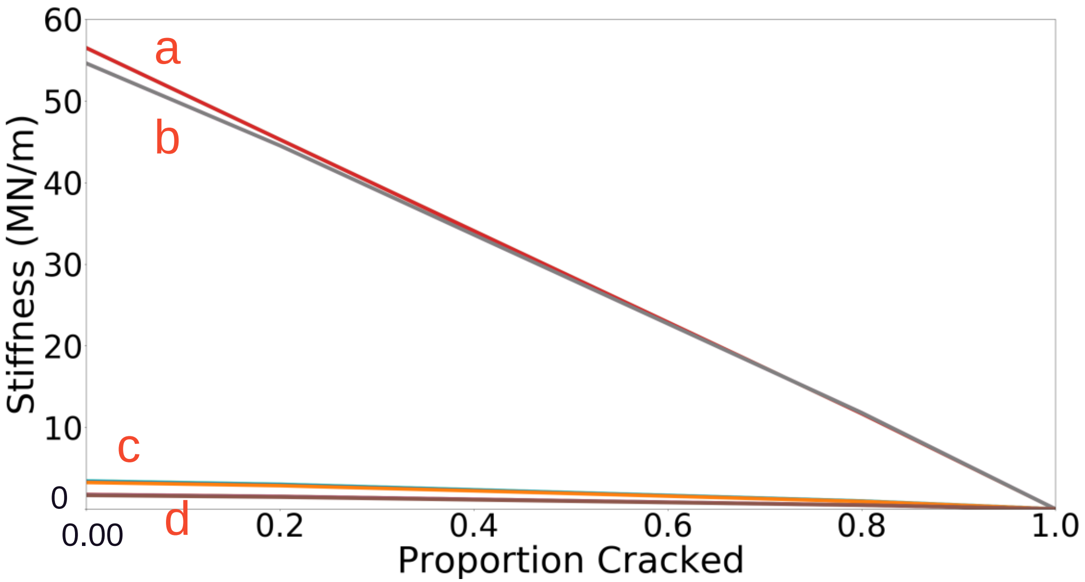




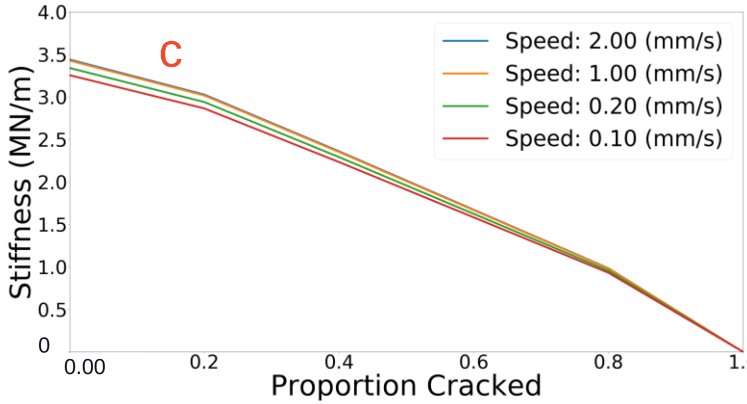
Damage as a Function of Crack Length

Results

- Strain-rate dependence of stiffness at a particular crack length for composites containing PE



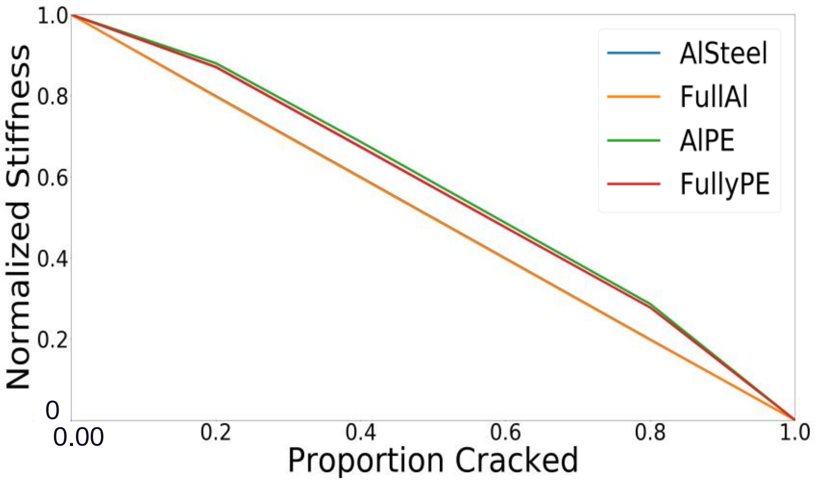
a) Al/Steel
b) Al/Al (grey)
c) Al/PE
d) PE/PE

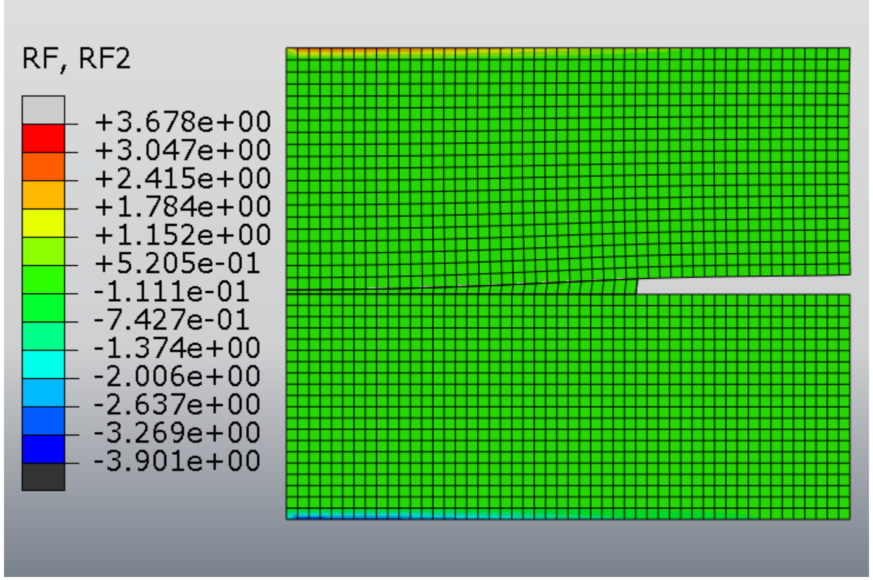


Damage as a Function of Crack Length

Results

- Strain-rate independence on normalized stiffness at a specific crack length
- But what’s up with this shape?
  - ○ Cohesive element weakening?

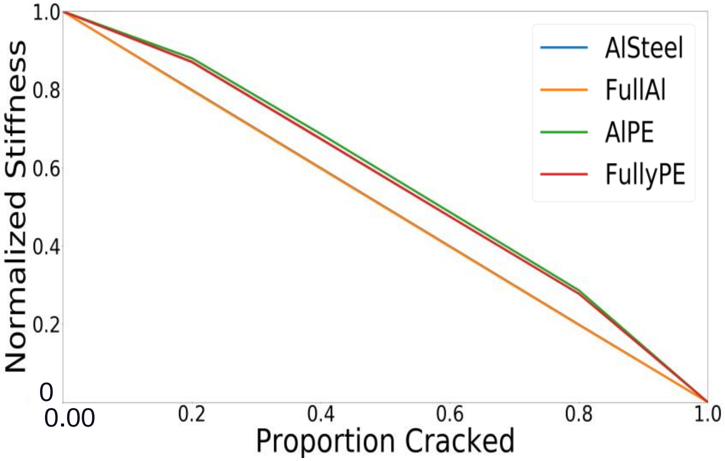


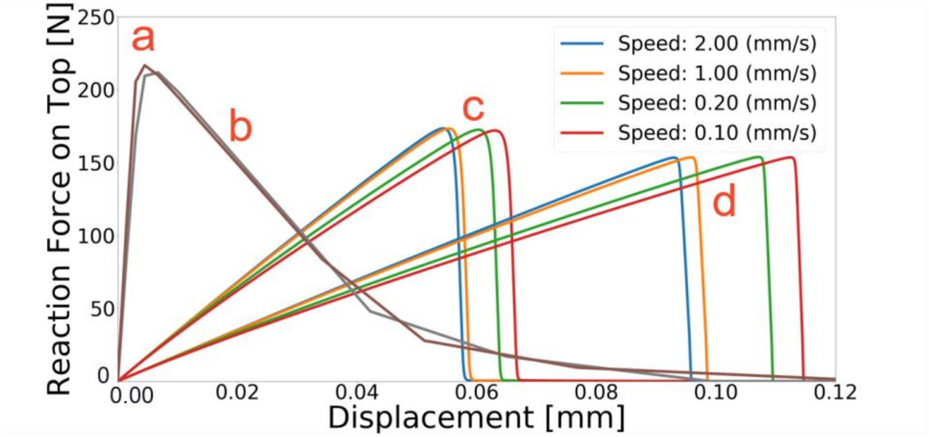


Questions / Future Work

Questions / Future Work

- What is causing this damage vs amount bonded relationship? Cohesive elements need to be better understood
- Look at stiffness/damage as a function of top face displacement (secants?)





a) Al/Steel (brown) b) Al/Al (grey) c) Al/PE d) PE/PE

- **Implement non-uniform bonding across the interface**
- **Simulate an inclusion composite rather than a laminar composite to more closely approximate materials of interest**
- **Anisotropy development?**

Acknowledgements

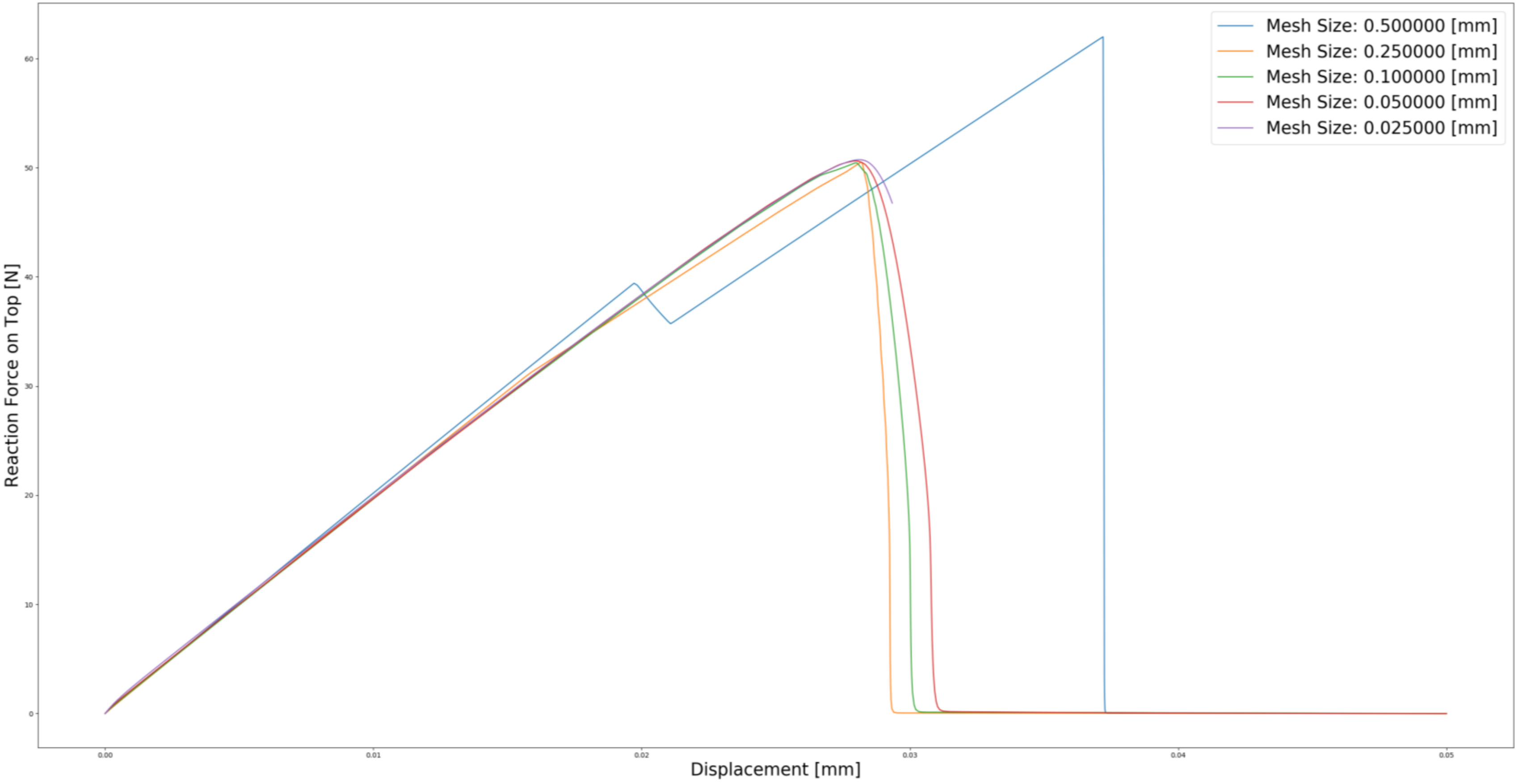
Thanks!

- Nathan Miller (technical mentor)
- Antranik Siranosian (mentor)
- Everyone

Questions?

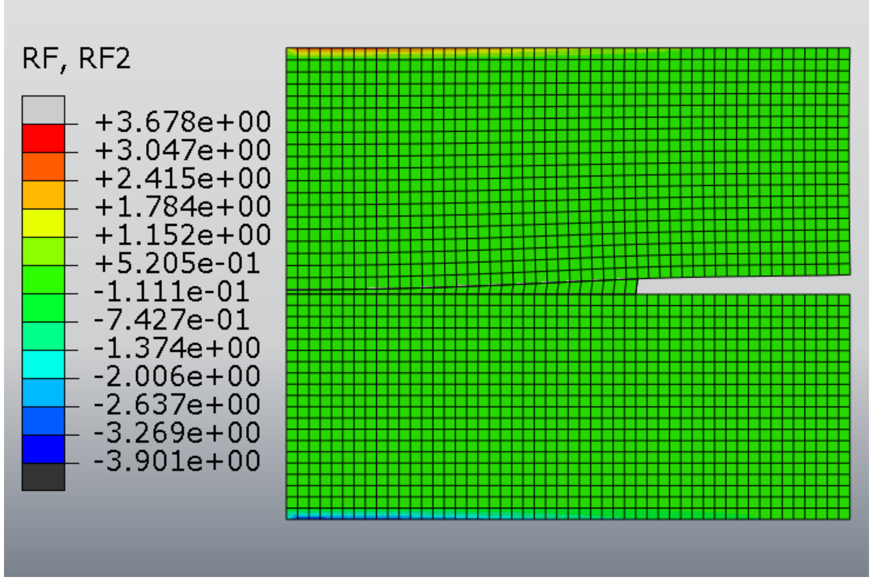
Mesh Size Convergence Study

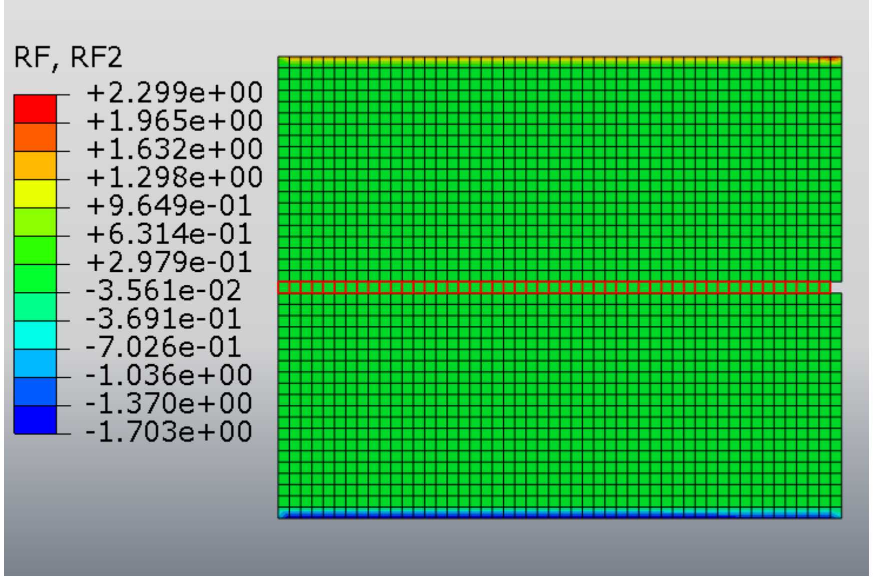
- Chose 0.1 mm as the mesh size because it is the first that shows the general curve

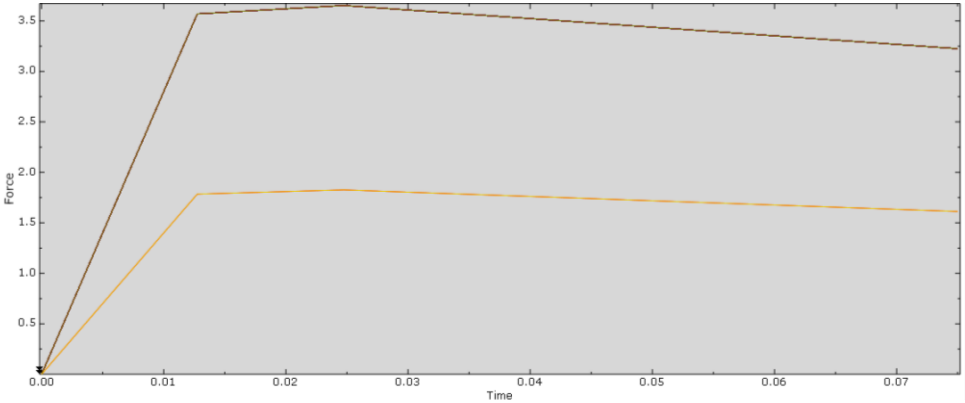


Difference in Deformation of PE and Steel when cohered to Al

- Cohesive elements lose stiffness as they pass a certain energy



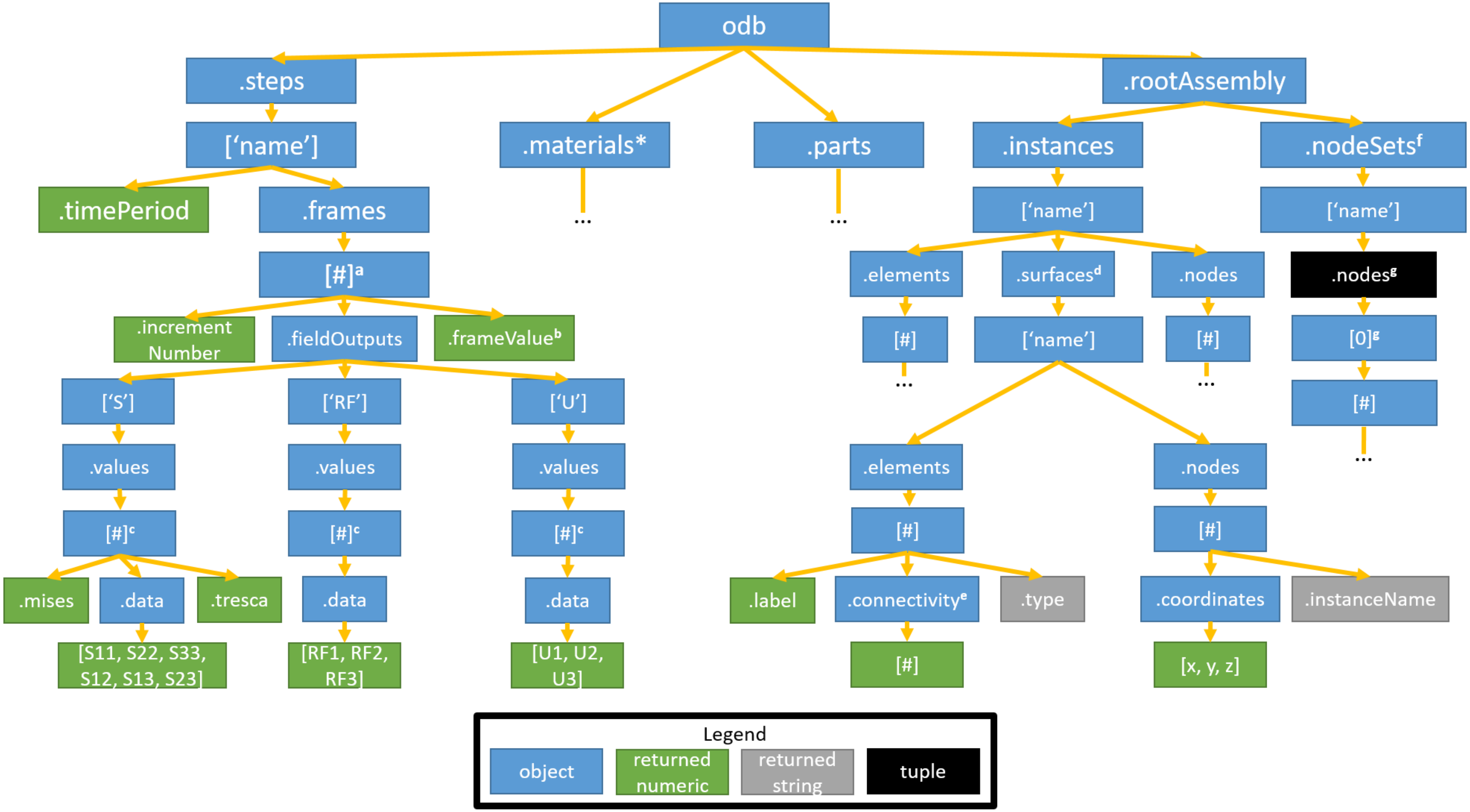




Difference in Deformation of PE and Steel when cohered to Al

- No Tie: 137020.25
- Half Tie: 137040.26
- Ideal: 114266.67

Odb reader tree



Odb reader notes

a) Each frame inside the .frames list represents the solution at a particular time in the simulation. A particular frame can be though of as a snapshot of the state of the model as it is being loaded in the step.

b) The frame value is the time associated with the frame. This can be though of as the time at which the snapshot was taken. In simulations with only one step, the first .frameValue will be 0 and the last .frameValue will be the timePeriod of the step.

c) A particular value in the .values list contains the information of a specific node or integration point where the fieldOutput has been calculated.

d) The surfaces found within an instance are linked with the part and are NOT the surfaces that were created within the assembly. I usually use these part-based surfaces for ties/contact since I am connecting different parts together.

e) The .connectivity list contains a list of the node labels that make up the element. For example, if an element connected the 3, 4, 6, 7 nodes, .connectivity would return [3, 4, 6 ,7].

f) The .nodeSets list (and similarly the .elementSets list) under the rootAssembly contains the sets and surfaces that were created in the Assembly. These sets and surfaces can contain elements and nodes from multiple different instances. I usually use these surfaces for boundary conditions and as references to simplify the calculations. For example, I assign a nodeset made of only the single element at the end of the part to easily reference it when calculating the length of the part.

g) The .nodes in the nodeSets (or .elements in elementSets) returns a tuple containing a single entry, so the first [0] is needed to access the actual list of nodes/elements within the set. The second index references a particular node/element within the set.